FOREWORD

By

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This is the first official publication of Caltrans California Seismic Hazard Map based on the latest understanding in earthquake science and earthquake engineering. This replaces California Division of Mines & Geology Open-File Report 92-01 for use in Caltrans. New technology of mapping, GIS is used to make the hazard map for wider applications. Caltrans criteria is clearly reflected in this report in that we use late Quarternary faults for our considerations. Also, we proved that the concept of MCE is appropriate for our purpose, considering that we deal about critical facilities for public safety. The author has a long experience in earthquake hazard assessment for critical facilities and has done the previus report for Caltrans while at California Division of Mines & Geology. I know him for more than 18 years.

- The new map is to be used for **A**cceleration factor of the **ARS** curves which will reflect the MCE and the distance of the fault, in conformity with scientific understanding of earthquake ground motion spectra. A guideline has been provided by the latest ATC-32.

- As surface fault rupture is critical, the map will also be used to evaluate fault displacement rupture hazards. Obviously, more investigation would be required if more definitive numbers are needed.

- To supplement traditional ground motion input data, Caltrans is interested in using modern strong motion simulations by modelling seismic sources in the Greens function method. This map will be used for the sources of earthquakes for generating such synthetic seismograms.

It is our intention to update the map as new information become available. As this is the first map, errors and omissions are naturally expected. We will make necessary corrections as soon as they are detected.

We hope that the public is well served by this effort. Our design engineers and consultants will find this report to be friendly and easy to use. It is published in color to make it more instructive.

I am pleased to release the report for public consumption as one of the products of Caltrans for public service.

A TECHNICAL REPORT TO ACCOMPANY THE CALTRANS CALIFORNIA SEISMIC HAZARD MAP 1996 (*BASED ON MAXIMUM CREDIBLE EARTHQUAKES)*

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1. INTRODUCTION

In earthquake country like California, safe and economical design of engineered structures requires consideration of the hazardous effects of future earthquakes. One effect, important in all of California, is ***ground shaking*** hazard. This has been considered by the California Department of Transportation (Caltrans) in the planning, design, and construction of bridges.

The Governor's Board of Inquiry on the 1989 Loma Prieta Earthquake (State of California, 1990) recommended that Caltrans updated and periodically revised standards, criteria, and specifications with the assistance of external expertise. Caltrans Seismic Advisory Board Report on the 1994 Northridge Earthquake (State of California, 1994) recommended that Caltrans should reconsider the technical assumptions leading to the deterministic map and prepare a new one to reflect current understanding of both seismic hazard and the way in which these values are used in bridge design. All these important recommendations are carefully considered in the preparation of this report, a revision of the Caltrans California Seismic Hazard Map 1996. Other recommendations pertaining to ground motion estimates are considered on a case by case basis.

For seismic design of important/critical structures, Roberts (1992) stated that Maximum Credible Earthquakes are used because the likelihood of such earthquakes occurring is great enough to be of concern and that probability of certain faults being active and the probability of recurrence rate or return period are not confidently known for most faults. Maximum Credible Earthquake concept implicitly taken into account such probability factors. Caltrans is applying current understanding of earthquake science in bridge engineering.

Other reasons for the basis of this revision are provided by reviewing the deveopment of a deterministic approach of the Caltrans Seismic Hazard Map (Mualchin, 1996). In a nutshell, it is demonstrated that:

Ž The approach is sound and practical based on our experience of more than two decades in making deterministic assessments.

Ž Faults for recent damaging earthquakes, supposedly having long recurrence or low probability are automatically included in the deterministic approach, for example, the 1992 Landers and 1994 Northridge earthquakes.

Ž Relating earthquake recurrence or probability to design/economic/useful lifetimes is not always a sound approach for safety considerations because earthquake cycles are largely unknown and lifetimes are conceptual and not fixed. Many civil structures end up having service lives far beyond original design assumptions and are often rehabilitated or retrofitted for continuing use. Deterministic approach avoids such discrepancies.

Ž Geological and historical records have revealed that earthquakes do not necessarily occur in cycles like clockwork and the nature of the timing of future earthquakes is fundamentally unknown. Deterministic approach avoids such speculations.

Ž The use of deterministic MCE is prudent, practical, and simple. The resultant ground motions from MCE are the most appropriate consideration for critical structures and for public safety because they are conservative. Conservatism in the ground motion estimates, mean or some level above the mean, can be introduced according to the specific needs.

Reviewing the ground motion criteria, Gates (1976) pioneered in integrating the three fundamental factors for bridge engineering in California, after the experience of the damaging 1971 San Fernando earthquake. These factors are: the peak **A**cceration and the corresponding spectra on **R**ock or "rock-like" material anticipated from the Maximum Credible Earthquake (MCE) of late Quarternary fault(s), and amplification of ground motion due to **S**oil condition at the site. The integrated result is popularly known as **ARS** curves, named after the first letters of **A**cceration, **R**ock spectra, and **S**oil amplification. Again, **ARS** curves are used for bridge design criteria.

Current Caltrans **ARS** curves for four generic sites conditions (i.e., 0'-10', 10'-80', 80'-150', and above 150' or alluvium thickness over bedrock or "rock-like" material) and a spectrum of periods of vibration are published in Seismic Design References (State of California, 1990). The **ARS** curves are revised to keep up with the latest understanding in the related fields. Ideas from ATC-32 (Applied Technology Council, 1996) will be useful to improve some aspects of **ARS** curves.

This report supercedes the California Division of Mines and Geology Open-File Report 92-01 by Mualchin and Jones (1992). It is a revised edition of the deterministic Caltrans California Earthquake Hazard Map which provides **A**cceleration factor of the **ARS** curves. The estimated **A**ccelerations in this map are required in developing the

ARS curves (State of California, 1990; Caltrans, 1993) for designing new bridges and retrofitting existing bridges.

Other significant earthquake hazards considered by Caltrans are soil liquefaction and surface faulting The relative importance of strong ground motion, liquefaction, and surface faulting hazards in California can be seen by comparing rough estimates of damage caused by the respective hazards during well-known historic earthquakes (Wiggins, 1989, and Algermissen, 1990).

PERCENT OF TOTAL DAMAGE FOR CALIFORNIA EARTHQUAKES

EARTHQUAKE	GROUND MOTION	LIQUEFACTION	SURFACE FAULTING
1906 San Francisco (M8)	70 - 90	10 - 30	<2
1971 San Fernando (M6.5)	95	4 - 5	<1
1987 Whittier-Narrows (M6)	100	0	0
1992 Landers (M7.25)	95	0	5
1994 Northridge (M6.7)	98	2	0

It is clear that liquefaction is not as widespread as compared to strong ground shaking hazard and surface faulting is restricted to a relatively small area near faults. Ground shaking is responsible for 70 to 100 percent of all earthquake damage.

Liquefaction hazard is anticipated at soft soil sites such as at bay mud sites of the San Francisco bay area. Surface faulting hazards are expected from shallow earthquakes. Caltrans consider surface faulting by avoiding siting of new bridges across late Quarternary faults and by evaluating their effects on existing bridges for retrofit. This consideration exceeds the Alquist-Priolo Special Zone requirement which is limited to Holocene faults only (Hart, 1994). Basic considerations of strong ground motion is presented in this report. Additional ground motion factors are incorporated for specific projects as considered appropriate by Caltrans.

The current edition of the "Fault Activity Map of California and Adjacent Areas" by Jennings (1994a) and the text that accompanies the map (Jennings, 1994b) were used as a primary source for fault information. Additional data were obtained from Caltrans consultants, Southern California Earthquake Center (SCEC), United States Geological Survey (USGS), universities, other organizations, and individuals specializing in specific fault(s), as will be indicated in the report. The assistance of external technical expertise is necessary in this type of work, as was done in the past.

Geographic Information System (GIS) technology is used in developing the Caltrans earthquake hazard mapping program (State of California, 1996). Faults are associated with several attributes for analysis.

This report describes the data and methodology used to produce the Caltrans California Earthquake Hazard Map 1996. Presented is a table of the faults and other potential seismic sources considered, the corresponding estimated magnitudes of the Maximum Credible Earthquake, and the sources of information used to derive the magnitudes.

A review of the data and methodologies used to estimate strong ground motion, as well as a discussion of the results, is included. The report will be revised on a continuting basis to keep up with latest understanding in earth sciences and earthquake engineering for bridge engineering.

2. SELECTION CRITERIA OF FAULTS

The main criteria used to select faults for seismic sources for this project bear on seismogenic potential. These criteria include: 1) geologic age of last displacement (late Quaternary and younger); 2) length of fault (10 km or more); 3) location of faults (California and adjacent areas; and, 4) occurrence of historic earthquakes.

In selecting faults or tectonic structures indicative of a concealed fault, a conservative approach was used. For example, the credibility of connecting individual faults to form a larger continuous fault, or the segmentation of fault zones into shorter individual fault strands likely to rupture in a single "maximum" event, and the use of historical seismicity to identify faults when the age of fault is otherwise questionable, were evaluated.

Faults associated with historical seismicity but with no verifiable late Quaternary displacement, or in some cases those that are structural extensions of late Quaternary faults, are included.

In general, faults selected had a length of at least 10 km, since this is considered to correspond to the maximum random earthquake (M6) in California, capable of generating the smallest PA's of interest (at about 10 km from the fault) in this project. Exceptions were made, however, to this minimum length requirement in areas where smaller faults, not in proximity to larger faults, could affect local areas.

No attempt was made in this report to evaluate earthquake recurrence intervals or activity status for faults except for fault activity inferred from the selection of late Quaternary faulting criteria. If a fault has not had displacement activity during the time span covered by the late Quaternary under the current tectonic setting, it is not likely to be a significant earthquake source. Conversely, if a fault has had significant activity during the late Quaternary, it could be the source of an earthquake during a reasonable period in the future and, therefore, is included in this report.

3. SEISMIC SOURCES

Seismic sources are based on: 1) the latest Fault Activity Map of California and Adjacent Areas (Jennings, 1994), 2) re-evaluation of the previous report by Mualchin and Jones (1992), and, 3) consideration of seismicity data on structures correlated with specific, known faults. As in the previous report, sources based on seismicity and other geophysical data alone are classified under Special Seismic Sources (SSS). The resulting map now includes about 270 faults.

The faults used for this project (Plate 1) are modified from the Fault Activity Map of California and Adjacent Areas (Jennings, 1994a). The sources considered, and references used in their evaluation, are listed in Table 1.

Most of the faults in the previous report by Mualchin and Jones (1992) were retained in this compilation, with little or no change. The occurrence of a few damaging earthquakes occurred since the above report does not require significant revision in the faults. Impact of the Landers and Northridge earthquakes are insignificant from the point of view of Maximum Credible Earthquake estimates and the resultant effects.

Selected faults were evaluated for style of faulting as well as length, dip, and maximum depth of the faults, all of which are necessary for estimating of maximum earthquake magnitudes. In general, the style of faulting (e.g., predominant relative sense of offset along the fault or fault zone) was taken from the available literature. Where no existing information was available, the style of faulting was based on the tectonic setting, predominant regional trend, and nearby fault plane solutions. When not explicitly stated in the literature, fault length was determined from Plate 1.

Modified Sources:

New information on causative faults of the Landers and Northridge earthquakes are incorporated in this report. These important earthquakes are recognized in this report, but they do not impact the previous report by Mualchin and Jones (1992).

Landers Earthquake Source - The surface rupture of the earthquake mapped by geologists (e.g., Sieh and others, 1993) is used in this report. However, inclusion of the new rupture zone does not require an increase in the adopted MCE for the fault zone. A magnitude of 7 1/2 is considered adequate for this earthquake source.

Northridge Earthquake Source - The Northridge earthquake is centered very close to the Northridge Hills fault section of the Simi-Santa Rosa-Northridge Hills fault zone. The precise location of the Northridge earthquake was a subject of careful scientific investigation (e.g., Hauksson and others, 1995) and is in the vicinity of the Simi-Santa Rosa-Northridge Hills fault. Due to the close proximity of the faults, anticipated ground motions from them are practically the same. Thus a radical revision on our previous report is needed except to recognize the Northridge earthquake source.

New Sources:

A number of new seismic sources are included in this report. These are noted with asterisk (*) in Table 1. Jennings' (1994a,b) compilation of fault activity made it possible to select the late Quarternary faults in a straightforward manner. There are a few exceptions, as will be stated below.

When faults used in this report are not named in Jennings (1994a,b), the names used are either those in the literature cited as references for the individual faults in Table 1, or are informal names applied for the use of this project. Informal names selected are based on geographical location or topographic features in the specific areas, or are alphanumeric based on the 1^o x 2^o sheets of the Geologic Atlas on which the fault is located (or adjacent to in the case of faults outside of California). Footnote 1 of Table 1 illustrates the convention adopted for informal fault names based on abbreviated Geologic Atlas Sheet or State names.

Cascadia Subduction Zone - This subduction zone became better understood since the last report. Caltrans examined this fault with their consultants (Geomatrix, 1994) and concluded that it may be able to produce a Maximum Credible Earthquake of M8.

Foothills Fault System - Jennings (1994a,b) compiled several late Quarternary faults in the Foothills Fault System which are indicated in this report. Rather than using only the entire mapped length of the western-most and eastern-most fault strands of the fault system in the previous report, all identified faults are used here.

The system is composed of predominantly minor, normal displacement faults, superimposed on major high-angle reverse faults, along the western flank and northern margin of the Sierra Nevada, would affect the east side of the Sacramento Valley, the northern part of the San Joaquin Valley, and the Sierra Nevada foothills areas. Many areas of late Cenozoic faulting and some areas of late Quaternary faulting were identified along both fault zones as a result of studies conducted after the 1975 Oroville earthquake along the Cleveland Hill fault, and for foundation investigations related to the proposed Auburn Dam. Portions of these zones have been seismically active in historic time.

Another reason for using these faults as potential seismic source zones is the continuation of crustal extension is affecting the Sierra Nevada uplift (Hart and others, 1984, pp. 3-4), and 2).

The maximum earthquake magnitude for the Foothills fault system for this report is based on recommendations for the Auburn Dam project (California Division of Mines and Geology, 1979).

<u>Special Seismic Sources</u>:

While most seismic sources in this report coincide with mappable faults, there are large and destructive earthquakes in California whose causative faults are not recognized from surface geologic observations, such as the 1892 Vacaville-Winters, 1983 Coalinga, 1987 Whittier Narrows, and 1989 Loma Prieta earthquakes. This type of hidden earthquakes is discussed by Stein and Yeats (1989). There are also dense concentrations of seismicity (not necessarily associated with large earthquakes) which do not correlate with surface patterns of faulting, such as the Brawley Seismic Zone in the Imperial Valley. An attempt was made to represent such sources and to identify them as Special Seismic Sources (SSS) for this project. It should be noted that the Loma Prieta earthquake source does not alter significantly the contours on Plate 1 except for local site effects.

Widely accepted theory holds that all crustal earthquakes result from sudden displacement of the earth along a fault. Some possible reasons why some causative faults may not be identified at the ground surface include:

1. Seismic slip is deep-seated and dies out before reaching the surface.
2. The surface exposures are concealed by alluvium or complex folding.
3. Sufficient surface and subsurface geological and geophysical studies have not been conducted.

Regardless of their origin, areas where these seismic events have occurred must be considered for planning, engineering design, and public safety. Examples of these SSS are approximated or inferred as discussed below.

<u>The Coast Ranges-Sierran Block Boundary Seismic Zone</u> - Numerous earthquakes along the geomorphic demarcation of the Coast Range and the Central Valley have been noted since the 1892 Vacaville-Winters earthquakes (M's 7). The most recent large event along this zone is the 1983 Coalinga earthquake (M6.7) which caused considerable damage in the Coalinga area.

Upon close examination, geoscientists are of the opinion that the tectonic structure and seismic activity along this zone can be understood as the interaction between the Coast Ranges and the Sierran Block. Because the seismic sources are not well defined at the surface, this zone is considered as a special seismic source for this project, and is identified as the Coast Ranges-Sierran Block Boundary Seismic zone. This zone includes the 1892 Vacaville-Winters and 1983 Coalinga earthquakes sources which are also discussed below.

The basis of the source delineation is based on the works of Wong and others (1988) and Wentworth and Zoback (1989). These papers have examined contemporary seismicity, tectonics, and geomorphic features of the zone, and present a plausible delineation of the zone. For the purpose of this project, the zone is constrained to pass through the estimated Vacaville-Winters 1892 earthquakes and the Coalinga 1983 earthquake sources. The adopted magnitude of the MCE for the zone is taken as M_W7 by using the 1892 Vacaville-Winters earthquakes. Although the likely dip of the source appears to be towards the west, the estimated ground shaking in Plate 1 does not take into account such factor. Additional information on this structure can be seen in Stein (1984), Stein and King (1988).

The 1892 Vacaville-Winters Earthquakes Source: Two destructive earthquakes occurred in this region in 1892. Because these earthquakes generated the strongest shaking in the Sacramento Valley and are now located near populated and developed areas, the seismic source zone should be considered. This seismic source zone is considered as part of the Coast Ranges-Sierran Block Boundary Zone. The following steps were taken to specify the seismic source zone.

The magnitude of the MCE was evaluated first, and an appropriate fault length for this magnitude was scaled from the magnitude versus fault length relationship while considering the assumed focal mechanism. The orientation of the fault was guided by the tectonic features of this region and also by the trend of the longer axis of the isoseismal curves of the highest intensity ratings for these earthquakes.

The magnitudes of the 1892 Vacaville-Winters events were estimated from intensity data by using correlations of magnitudes versus maximum intensity or various isoseismal areas. Magnitude estimates range from 6.4 to 7.0 (Dale, 1977; Toppozada and others, 1981; Wong, 1984). Isoseismal areas of given intensities for the 1892 events are generally larger than those for the 1983 Coalinga (M6.7) earthquake (Toppozada and others, 1981; Stover, 1983), both events are in a similar tectonic setting. We believe that comparisons of isoseismal areas appropriately indicate differences in magnitudes of earthquakes that are in similar tectonic settings, and consequently adopt M7 for the MCE for Vacaville-Winters source zone.

Examination of focal mechanisms of earthquakes and the style of faulting in the western margin of the Great Valley of California (Eaton and others, 1983; McNally, 1983) indicates similar thrust type mechanisms for the 1983 Coalinga and the 1978 Madison earthquakes. The latter event is located about 18 km north of Winters. Since these earthquakes are in the same general tectonic setting, we conclude that the 1892 events may also have been characterized by a thrusting mechanism.

The length of the 1892 earthquakes source zone is estimated by adopting M7 and applying Slemmons (1982), Bonilla and others (1984), and Wells and Coppersmith (1994) to be about 35 km based on regression of fault length and magnitude appropriate for thrust faulting. Orientation of the seismic source is guided by the general trend of faults in this tectonic province and also by the direction of the longer axis of the maximum isoseismal curves. It is estimated to be approximately NNW-SSE. Figure 1 illustrates the method.

The correlation of maximum iso- seismal curves with fault rupture geometry and location is in agreement with other California earthquakes, for example, the 21 October 1868 earthquake on the Hayward fault, the 26 March 1872 earthquake on the Owens Valley fault, and the 24 April 1890 earthquake on the San Andreas fault (Toppozada and others, 1981). The seismic source is drawn as a dotted line in Plate 1 that passes through the approximate center of the meizoseismal curves. This is an inferred source and should not be confused with surficially exposed seismic sources. It does not represent a specific fault location.

The 1983 Coalinga Earthquake Source: Location and magnitude (M6.7) of the 1983 Coalinga earthquake were well-determined (e.g., Uhrhammer and others, 1983). There was no surface fault rupture associated with the main event so that the surface source representation is not straightforward. This source zone is also considered as part of the Coast Ranges-Sierran Block Boundary Zone.

The 1983 event indicates that the MCE magnitude for this source should be M6.7 or greater. We conservatively propose an MCE of M7 having a rupture length of about 35 km aligned along the aftershock zone. The proposed length is estimated from the regression models of Slemmons (1982), Bonilla and others (1984), and Wells and Coppersmith (1994) and is in general agreement with the extent of the aftershock distribution of the 1983 event.

It should be noted that an aftershock (M5.2) of this earthquake was accompanied by surface-rupture along the Nunez fault (Hart and McJunkin, 1983). The style of faulting was dominantly reverse slip but some right-slip was recorded. However, the Nunez fault lies west of the mainshock source as delineated by the aftershock zone (Eaton and others, 1983).

The 1983 Coalinga earthquake source is indicated by a dotted line in Plate 1 and should be considered as an inferred fault, as distinguished from a well documented surface or near-surface fault. This source also is shown on Plate 1 as Anticline Ridge because an anticlinal structure is present in this location at depth.

There is still some uncertainty over whether the source is a high-angle, NE-dipping or a shallow, SW-dipping thrust. Both anticlinal planes appear active in seismicity cross section throughout the aftershock zone. For the purpose of this study, the selection of the fault plane orientation is immaterial since the distance for estimating PA is measured from the surface projection of the NW-SE trending linear zone of activity.

The Brawley Seismic Zone - Seismicity data show a dense continuous distribution of earthquakes from the northern end of Imperial fault to what is shown on our map as the southern end of the San Andreas fault, (e.g., Johnson and Hill, 1982; Johnson and Hutton, 1982). There has been no report of surface faulting within this seismic zone although, the seismicity is clearly continuous throughout. This zone is known as the Brawley Seismic Zone.

For the purpose of this project, we represent this SSS by a dotted line through the middle of the NW-SE trending seismic zone in Plate 1 and assign M 6 1/4 as the MCE. The choice of this magnitude is based on the numerous occurrences of small magnitude events, none exceeding the proposed magnitude, and by the length of the zone.

<u>The Elysian Park Seismic Zone</u> - Another destructive earthquake with moderate magnitude (M5.9) occurred on October 1, 1987 on a subsurface fault in Los Angeles county. The location of the source is at about 15 km northwest of the northern terminus of the Whittier fault. This event is known as the Whittier-Narrows earthquake, and is studied extensively by Hauksson and colleagues, for example, Hauksson and others (1988), Jones and Hauksson (1988), Hauksson and Salvidar (1989), and Hauksson and Jones (1989a,b). The seismic source zone associated with the earthquake is a band of approximately 15 km wide (see Figure 12, Hauksson, 1989).

For the purpose of this map, the source zone is classified as a special seismic source because the fault rupture is not exposed to the surface. The zone is delineated imperfectly, as indicated in Plate 1, near the middle of the Hauksson's Elysian Park Fault zone, with the assumptions that the source is dipping to the north and most of the earthquakes are subsurface events.

Furthermore, the source is offset to the northeast of the northern terminus of the Whittier fault. The magnitude of the MCE is approximated as M6 3/4 using the 1971 San Fernando and the above earthquake magnitudes as a base.

It should be recognized that other studies proposed a more complex configuration and tectonics of this region, and perhaps a larger magnitude, for example, Davis and Namson (1989), Namson and Davis (1989), Davis and others (1989), and Davis and Hayden (1987). The study of earthquake sources and the associated hazards in the Los Angeles area is an on-going activity and the present effort is to be viewed as a start that should be improved in future.

4. ESTIMATION OF MAXIMUM CREDIBLE EARTHQUAKE (MCE) MAGNITUDE

Maximum Credible Earthquake (MCE) is defined as the largest earthquake that appears to be reasonably capable of occurring under the conditions of presently known "geological framework" (see California Division of Mines and Geology, 1975, for a more complete description). More recent discussions can be seen in Slemmons and dePolo (1985) and Krinitzsky and others (1993). The concept is sound and the application is mature, being used for more than two decades.

The maximum earthquake is expressed in terms of magnitude which is estimated by 1) using correlations between fault parameters (fault length, fault displacement, and fault area) and earthquake magnitudes, or 2) the largest historical event to have occurred along a particular fault. The correlations applied are derived from historical observations of worldwide earthquakes (for example, Slemmons, 1982; Bonilla and others, 1984; Wells and Coppersmith, 1994).

For the sake of uniformity, fault length and fault area are used to obtain the MCE magnitudes for particular faults in this project. Fault area is computed by the combined considerations of fault length, fault dip, and assumed maximum width of fault. The fault surface is assumed to be planar.

Fault length is measured from Jennings (1994a), supplemented by more recent publications when available. Fault length measurements are straightforward for vertical and high-angle faults because their surface traces are generally linear. However, low-angle faults generally are characterized by a sinuous surface trace. This sinuosity complicates fault length measurement. Adjustments for the effect of topography and dip of the fault are made for applicable cases in this study.

While it has been assumed in the past that no more than half of the total fault length will rupture during a single MCE event (Albee and Smith, 1966), this is not always so. For example, in the 1943 Tottori, Japan earthquake, the rupture propagated beyond the mapped length of the Shikano fault (Richter, 1958). As a result, it is felt justifiable to use more than half of the total fault length for the estimation of the MCE magnitudes, especially for shorter faults. MCE magnitudes are estimated by using: (a) half the total length for longer faults (greater than about 50 km), (b) approximately two-thirds of the total length for intermediate faults (about 25 to 50 km), and (c) the total length for shorter faults (less than about 25 km).

Additionally, the use of a larger fraction of the total length is appropriate for well-defined and highly active or high slip-rate faults. Slemmons and dePolo (1985) supported such a method (the use of more than half of fault length) when they stated that the use of one-half rupture lengths for short faults (on the order of a few kilometers to ten ± kilometers length) is not conservative and does not appear to be valid for many cases.

We use the concept of segmentation in cases where the continuity of fault is unlikely, and then use the longest fault segment for estimating the MCE magnitude for that fault. The segmentation of fault systems involves the identification of individual fault segments that appear to have continuity, and the same characteristic and orientation which suggest that a segment will rupture as a single unit (Slemmons, 1982). Individual fault segments have different characteristics relative to adjacent segments, or are separated from adjacent segments by identifiable discontinuities. However, the use of segmentation could cause underestimation of MCE, as was documented in a case study of the 28 October 1983 Idaho earthquake (Freeman and others, 1986). The final magnitude value adopted is specified to the nearest quarter of a magnitude unit.

The surface-wave magnitude (Ms) used by Slemmons (1982) and Bonilla and others (1984) is assumed to approximate Moment Magnitude (Mw) values. The Mw is the appropriate magnitude scale required for estimating peak acceleration from modern attenuation relationships. Wells and Coppersmith (1994) used Mw.

In some cases where there is extensive information and studies for particular faults, we use previously estimated MCE magnitude values, for example, the Foothills fault system (Mw 6.5) is based on the study for the Auburn Dam project (California Division of Mines and Geology, 1979) and the San Andreas fault (Mw 8) from the 1906 San Francisco earthquake. Table 1 lists the estimated MCE magnitudes for the seismic sources considered in this project.

5. ESTIMATION OF STRONG GROUND MOTION

Ground shaking from earthquakes results from the combination of several factors. Factors affecting severity of damaging shaking from earthquakes may be grouped under those due to the effects of: 1) the source, including the size of the event, type of faulting, complexity of rupture; 2) the propagation path, including an elastic attenuation, scattering, and geometrical spreading or distance; and 3) the site, which includes amplification or reduction due to local subsurface geology and topography.

Taking these factors into consideration, ground motion can be estimated by theoretical and empirical methods, using deterministic and stochastic approaches. However, it is impractical to calculate ground motion from theory for all seismogenic sources statewide. Regional variation of parameters necessary for theoretical estimates are poorly known, and the cost of determining parameter values, such as the physical properties of the medium, is too high for statewide application. In the present study, local geologic effects are not considered because it is impractical to obtain the necessary data statewide.

This map is to provide the upper bounds of input peak motion on rock and stiff soil sites for scaling purposes (of design spectra) so the more costly, sophisticated methods of estimating ground motion need be employed only on a site specific basis.

A common method of estimating strong ground motion for engineering application is based on empirical relationships between three parameters: 1) earthquake magnitude; 2) strong-motion parameters (in our case, peak acceleration), and 3) the "<u>distance</u>" from the earthquake sources to strong-motion recording stations (fault trace distance as measured on the map is used here). The reliability of the derived relationships depends on the quality and quantity of data, as well as the ranges of distances and magnitudes used in the analysis.

The attenuation regression models chosen may incorporate physical and other constraints. For example, Campbell (1981) fixed the attenuation rate of the far-field peak acceleration to be realistic beyond the range of distance of the available data. Campbell (1981) also restrained the relationship in such a way that peak acceleration is independent of magnitude at the source (the fault rupture surface). In other cases, Joyner and Boore (1982) constrained the relationship to be magnitude-independent in shape. All these considerations are complex and comparison between different relationships is not clear and oftentimes controversial. For example, there are different opinions about which "<u>distance</u>" (epicentral distance, hypocentral distance, nearest fault distance, or center of energy-releasing distance) should be used for deriving these relationships.

Except for near-field studies, relationships using various distance parameters are in rather good agreement, and their differences are not significant. Fault trace distance is used in this report.

Major advances in the development of strong-motion estimation techniques in the western United States occurred during three periods, and were strongly influenced by the occurrence of significant earthquakes. In the earliest period, before the 1971 San Fernando earthquake, extensive use was made of estimating peak acceleration from expected intensity (e.g., Neumann, 1954; Hershberger, 1956). Barosh (1969) reviewed these earlier methods.

In the second period, immediately following 1971, intensive efforts were made to estimate peak acceleration directly from magnitude and distance-to-source methods, utilizing strong-motion records from the 1971 San Fernando earthquake and previously available records (e.g., Donovan, 1974; Trifunac, 1976; Schnabel and Seed, 1973; Boore and others, 1980). McGuire (1978) presented a summary of attenuation functions that included this period. One particularly notable set of relationships developed by Schnabel and Seed (1973) became the industry standard for many years.

The third period followed the occurrence of the 1979 Imperial Valley earthquake which yielded the much needed near-field strong-motion records. Intense analysis was again made of these and other strong-motion data, including other large and significant earthquakes elsewhere (Campbell, 1981; Joyner and Boore, 1981; Bolt and Abrahamson, 1982; Boore, 1982; Seed and Idriss, 1982; Idriss, 1985; Joyner and Fumal, 1985; Campbell, 1987; Campbell, 1989).

In addition to the attenuation relationships stated here and those published elsewhere, there are probably several others developed by individuals and consulting firms for their own use. Many of these are proprietary or have not received close scrutiny by experts. For this reason, this report considered only those attenuation relations in the published literature. Although one does not see drastic differences between these published results, it is reasonable to assume that the more recent studies are more realistic, particularly in the near-field, by virtue of the fact that they use more actual physical data and more refined methods of analysis.

Because the various sets of attenuation curves do not differ greatly, and yet are not coincident, one has not been selected over the others. All have good features and shortcomings. Here, the arithmetic mean of these curves (except Figures 9 and 10) is used (Figure 11). Reanalysis of currently available data probably will not significantly improve the existing relationships. Considerations of different styles of faulting in earthquakes, and instrumental site response may improve the accuracy of peak acceleration attenuation curves. However, much more detailed information needs to be collected, examined and analyzed before such relationships are available. In consideration of practical limitations, the average curves in Figure 11 are used in this report. It should be noted that data from the recent Loma Prieta earthquake do not change significantly the adopted attenuation relations of this report.

It should also be noted that most published attenuation relationships are applicable for estimating mean PA's. These relationships contain some variability and uncertainty in 1) PA's (usually provided by the authors), and 2) distances. Figure 13 gives some indication of variation in PA contour, namely, variation in fault distance for PA of 0.2g generated by an earthquake source with M6 1/4. Specifically, the 0.2g contour generated around a fault with M6 1/4 on Plate 1 is marked at a distance of about 15 km from the fault, and this distance could range from a few km to tens of km from the fault with varying probabilities.

The knowledge of distance from the seismic source is necessary to apply attenuation relationships to estimate peak acceleration. For this study, distance is measured from the actual or inferred trace of the fault corresponding to a specified level of peak acceleration. The majority of faults considered here are near vertical. The more realistic approach would be to use fault plane distances. PA estimates by different authors can differ significantly in the near-field regions above inclined fault planes, as demonstrated by Mualchin (1985), because of differences in the definition of distance. Although fault plane distance is preferred, insufficient statewide information on fault dip and width precludes proper applications. Thus, PA's are probably underestimated above low-angle faults which are present mostly in the Transverse Ranges, the Northern Coast Ranges, and in part of the Basin and Range, and the southwestern part of the Klamath Mountains provinces. However, estimates in this report are the most practical on a statewide basis at this time.

This report used the attenuation curves in Mualchin and Jones (1992). A new one is under preparation by the author for the next edition of the map.

6. CONSTRUCTION OF STRONG GROUND MOTION CONTOURS

The method used to construct the peak acceleration (PA, Plate 1) is straightforward and requires 1) delineation of the fault source on a map, 2) the MCE for the fault, and 3) a suitable attenuation relationship showing the decrease in peak acceleration with distance from the fault. The attenuationship relation appropriate for the MCE was used to determine the distance to a specified level of peak acceleration. The locus of all points having the same peak acceleration from one or more faults in proximity forms the desired contour. This is done for all desired levels of peak accelerations (0.1g, 2g, 0.3g, 0.4g, 0.5g, 0.6g), as stated below.

In practice, semicircles having a radius equal to the distance corresponding to the desired levels of peak accelerations are drawn from the ends of the fault, and marks are made on both sides of the middle section or bending point(s) of the fault at the same distance. A tracing of the fault is superimposed to smoothly connect the above semicircles and the marks of the same peak accelerations to generate the desired contours. This procedure is repeated for each increment or decrement of peak acceleration.

In many instances, a number of faults of varying sizes with different orientations and MCE's are present in proximity. The effects of smaller faults may be overshadowed by the larger ones in proximity. In other cases, the combined effect is present and care was taken to connect the same level of peak acceleration-contour consistently.

Peak accelerations are contoured in steps of 0.1g starting from 0.2g until the maximum level of 0.6g is reached near to the fault. Faults with MCE's less than about M 6 3/4 are not considered capable of producing peak accelerations exceeding 0.6g according to the adopted attenuation curves in Figure 10. The level of 0.1g is assumed to coincide with that expected from maximum random events in California.

Attenuation relationships suggest that earthquakes with magnitude greater than 6 3/4 can generate peak accelerations higher than 0.6g in the near-field region. In fact, peak accelerations exceeding 1.0g have been recorded in several instances during recent earthquakes. However, there are numerous uncertainties in the near-field region, such as: 1) distance to the source; 2) variable nature of rupture mechanism for different earthquakes; 3) insufficient near-field data and undue influence in curve-fitting by far-field data; 4) strong dependency of near-field PA (rich in high-frequency or short wavelength) on heterogeneity of the propagating medium, especially as affected by local geology; and,

5) the nature of saturation of PA's in the near-field.

Additionally, there are also uncertainties in the engineering significance of high PA's, such as poor correlation of recorded PA's and building performance (Applied Technology Council, 1982). Because of these uncertainties, our map is limited to a maximum PA of 0.6g. This is not intended to imply that 0.6g is the maximum possible, but rather to indicate the upper level of peak accelerations known to occur with less controversy. In regions close to the sources where PA would exceed 0.6g, one should apply attenuation relationships with caution.

7. COMPARISON WITH OTHER GROUND MOTION MAPS

In the previous report by Mualchin and Jones (1992), the following maps were compared:

Alfors and others, 1973; Greensfelder, 1974; Algermissen and Perkins, 1976; General Services Administration, Public Building Service, 1978; Kiremidjian and Shah, 1978; Applied Technology Council, 1978; Algermissen and others, 1982; American National Standards Institute, 1982; International Conference of Building Officials, 1985; Structural Engineers Association of California, 1985; State Building Standards Commission, 1985; Veterans Administration, 1986; Building Seismic Safety Council, 1986; Department of the Army, 1986; Wesnousky, 1986; Building Seismic Safety Council, 1987; International Conference of Building Officials, 1988; Structural Engineers Association of California, 1988; State Building Standards Commission, 1988.

Some are deterministic and others are probabilistic. All have limitations and specific intended uses. Neither type of map is necessarily superior. For critical structures like bridges and dams, deterministic maps are more preferable as it is used by Caltrans.

From the recent earthquakes of California and Japan, it is clear that probabilistic maps did not provide realistic estimates for low active faults. The Kobe and Landers earthquakes are supposed to have long recurrence intervals but none can predict when they will produce the next damaging earthquakes. In this sense, deterministic maps realistically provide estimates of anticipated earthquake hazards.

8. FUTURE MAPS

A future map will be for the purpose of functional evaluation of important bridges. Lesser earthquakes than the MCEs will be considered based on the concept of recurrence intervals of earthquakes. Magnitudes of desired recurrence intervals will be estimated. The recurrence will be proportionally related to the conceptual life of important bridges. Resultant ground motions from the above magnitudes will be produced as in this report.

Future maps will incorporate more of the geometry of dipping faults and focal depths for measuring distance of areas located in the dip direction for peak acceleration estimation. As in the past, the current fault map (Jennings, 1994a) is, as a whole, lacking in fault dip and maximum fault width information. This should be provided by interpretation of focal mechanism and maximum focal depth data of earthquakes in conjunction with other new geological and geophysical fault data. The focal mechanism data should also be utilized when characterizing style of fault movements because such information is lacking or poorly known for many faults. Better knowledge of styles of faulting would improve magnitude estimation because refined magnitude estimation is based on fault styles.

In the future, attempts would be made to consider the effect of local geology on peak acceleration in an approximate manner, yet meaningful and affordable on a large scale map like Plate 1.

Seismic sources/faults be classified into three or four categories according to their activity (Allen, 1989) by using probabilities of earthquake magnitude (not directly of ground shaking) occurrences similar to U.S. Geological Survey (1988) study for the San Andreas system and SCEC (1995) for Southern California, slip rates, or recurrence interval values of the MCE's. The faults and/or the corresponding estimated ground shaking contours be color-coded according to the category of the activity classification.

Finally, ground shaking parameters other than peak acceleration should be estimated and mapped for engineering applications.

9. SUMMARY

This is a revision of the Caltrans California Seismic Hazard Map for bridge engineering. It is to be used for estimating **A**cceleration factor of the **ARS** curves. Because of surface faulting hazard in the vicinity of faults, the map should also be used for evaluation of surface displacement hazard at or near bridges.
The map is also intended for use in source models for computing anticipated strong ground motions by using various strong motion seismology methods of Greens functions. Because of the dynamic nature of earthquake science, the map will be revised on a regular basis to keep up with the latest knowledge.

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13. TABLE 1
SEISMIC SOURCES, MCE MAGNITUDES, AND SELECTED REFERENCES

Fault[1]	Style[2]	Mag.[3]	Reference Û	Fault Code
AIRPORT LAKE	NL	6 ¾	Roquemore, 1981 Mualchin and Jones, 1992 Jennings, 1994	APL
AL-4* (Unnamed)	XX	6	Jennings, 1994	AL4
ANTELOPE VALLEY/E	NL	7	Dohrenwend, 1982 Mualchin and Jones, 1992 Jennings, 1994	AVE
ANTELOPE VALLEY/W	NL	7	Dohrenwend, 1982 Mualchin and Jones, 1992 Jennings, 1994	AVW
ANTIOCH	ST	6 ¾	Hart and others, 1981 Hart and others, 1983 Mualchin and Jones, 1992 Jennings, 1994	ATH
ARRASTRE CANYON*	XX	7 ¾	Jennings, 1994	ACN
ASH HILL	NO	6 ¾	Bryant, 1989 Mualchin and Jones, 1992 Jennings, 1994	AHL
BAILEY*	XX	6 ½	Jennings, 1994	BLY
BALD MTN-BIG LAGOON*	XX	7 ¼	Jennings, 1994	BML
BARTLETT SPRINGS ROUND VALLEY (Ukiah Sheet)	ST	6 ¾	Dehlinger and Bolt, 1984 McLaughlin and others, 1985 Mualchin and Jones, 1992 Jennings, 1994	BSR
BATTLE CREEK	NL	6 ½	Harwood and Helley, 1982 Hart and others, 1984 Hart, 1986 Mualchin and Jones, 1992 Jennings, 1994	BCK
BEAR MOUNTAIN/W*	NL	6 ½	Jennings, 1994	BMW
BENTON VALLEY*	XX	6	Jennings, 1994	BVY
BIG BEND*	XX	6 ¼	Jennings, 1994	BBD
BIG BEND-WOLF CREEK-MAIDU- BEAR MOUNTAIN/E*	NL	6 ½	Jennings, 1994	BWM
BIG PINE	ST	7 ¼	Mualchin and Jones, 1992 Jennings, 1994	BPN
BIG VALLEY (Santa Rosa Sheet)	NL	6 ¼	Wagner and Bortugno, 1982 Mualchin and Jones, 1992 Jennings, 1994	BIV

BLACKWATER	ST	6 ½	Smith, 1964b Mualchin and Jones, 1992 Jennings, 1994 Hsu and Wagner, in prep.	BLW
BLYTHE GRABEN	NL	6	Purcell and Miller, 1980 Nagata and others, 1982 Mualchin and Jones, 1992 Jennings, 1994	BGN
BRAWLEY-IMPERIAL/E	ST	7	Fuis and others, 1982 Johnson and Hutton, 1982 Sharp, 1982 Kahle and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	BIE
BRAWLEY-IMPERIAL/W	ST	7	Fuis and others, 1982 Johnson and Hutton, 1982 Sharp, 1982 Kahle and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	BIW
BRAWLEY SEISMIC ZONE	ST	6 ¼	Fuis and others, 1982 Johnson and Hutton, 1982 Sharp, 1982 Mualchin and Jones, 1992 Jennings, 1994	BSZ
BRIDGEPORT BASIN-ROBINSON CREEK/N	NL	6 ½	Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	BRN
BRIDGEPORT BASIN-ROBINSON CREEK/S	NL	6 ½	Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	BRS
BUCK RIDGE (San Jacinto Zone)	ST	6 ½	Mualchin and Jones, 1992 Jennings, 1994	BUR
CABRILLO	RO	6 ½	Fischer and others, 1983 Greene and Kennedy, 1986 Mualchin and Jones, 1992 Jennings, 1994	CBR
CALAVERAS-PACINES-SAN BENITO	ST	7 ½	Slemmons and Chung, 1982 Mualchin and Jones, 1992 Jennings, 1994	CPS
CALICO-HIDALGO/E	ST	7 ¼	Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	CHE
CALICO-HIDALGO/E	ST	7 ¼	Bortugno and Spittler, 1986 Mualchin and Jones, 1992	CHW

			Jennings, 1994	
CAMBRIA	RE	6 ¼	Buchanan-Banks and others, 1978 Kilbourne and Mualchin, 1980a Pacific Gas and Electric, 1988 Mualchin and Jones, 1992 Jennings, 1994	CAR
CAMEL PEAK*	XX	6 ½	Jennings, 1994	CPK
CAMP ROCK- JOHNSON VALLEY	ST	6 ¾	Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	CJV
CASA LOMA-CLARK* (San Jacinto Zone)	ST	6 ¾	Jennings, 1994	CLV
CASCADIA SUBDUCTION ZONE*	RE	8 ½	Jennings, 1994	CSZ
CASMALIA	RE	6 ¾	Hall, 1987 Pacific Gas and Electric, 1988 Mualchin and Jones, 1992 Jennings, 1994	CMA
CEDAR MOUNTAIN/E*	XX	7	Jennings, 1994	CME
CEDAR MOUNTAIN/W*	XX	7	Jennings, 1994	CMW
CENTINELA* (Baja California)	XX	6 ¼	Jennings, 1994	CTA
CENTRAL AVENUE*	XX	6 ½	Jennings, 1994	CAV
CHARNOCK	ST	6 ½	Barrows, 1974 Ziony and others, 1974 Mualchin and Jones, 1992 Jennings, 1994	CNK
CHATWORTH/N*	XX	6 ½	Jennings, 1994	CWN
CHATWORTH/S*	XX	6 ¼	Jennings, 1994	CWS
CHEMEHUEVI GRABEN	NL	6	Purcell and Miller, 1980 Nakata and others, 1982 Mualchin and Jones, 1992 Jennings, 1994	CGR
CHINO*	ST	6 ½	Bortugno and Spittler, 1986 Jennings, 1994	CNO
CLAMSHELL-SAWPIT CANYON	RO	6 ½	Mualchin and Jones, 1992 Jennings, 1994	CSC
CLEARWATER	NO	6 ¾	Mualchin and Jones, 1992 Jennings, 1994	CWT
CLEGHORN-NORTH FRONTAL	RE	7 ¾	Mualchin and Jones, 1992 Jennings, 1994	CNF
CLEVELAND HILL/E- PAYNES PEAK- SWAIN RAVINE*	NL	6 ½	Jennings, 1994	CPR
CLEVELAND HILL/W*	NL	6 ½	Jennings, 1994	CHL
COAST RANGES- SIERRAN BLOCK	RE	7	Wong and others, 1988 Von Huene and others, 1989	CSB

BOUNDARY ZONE			Wentworth, 1989 Wentworth and Zoback, 1989 Wong, 1989 Stein, 1989 Mualchin and Jones, 1992	
COLLAYOMI	ST	6 ½	Wagner and Bortugno, 1982 Hart and others, 1983 Mualchin and Jones, 1992 Jennings, 1994	CYM
CONCORD	ST	6 ½	Mualchin and Jones, 1992 Jennings, 1994	COD
CORDELIA	ST	6 ½	Wagner and Bortugno, 1982 Hart and others, 1983 Mualchin and Jones, 1992 Jennings, 1994	CDA
COYOTE CREEK-SUPERSTITION MOUNTAIN (San Jacinto Zone)	ST	7 ½	Mualchin and Jones, 1992 Jennings, 1994	CSM
CRAFTON HILLS*	XX	6 ½	Jennings, 1994	CRH
CYPRESS POINT*	XX	6	Jennings, 1994	CPT
DAVIS CREEK*	XX	6	Jennings, 1994	DCR
DEATH VALLEY/C	NO	7 ¾	Mualchin and Jones, 1992 Jennings, 1994	DVC
DEATH VALLEY/S	ST	7 ¾	Davis, 1977 Mualchin and Jones, 1992 Jennings, 1994	DVS
DEEP SPRINGS*	XX	6 ¾	Jennings, 1994	DSP
DOGWOOD PEAK-RAMSHORN*	NL	6 ½	Jennings, 1994	DPR
DUCK FLAT (Nevada)	NL	6 ½	Stewart and Carlson, 1978 Nagata and others, 1982 Mualchin and Jones, 1992	DFN
DUNNIGAN HILLS	RE	6 ½	Mualchin and Jones, 1992 Jennings, 1994	DUH
DURWOOD	NL	6 ½	Browne, 1984 Mualchin and Jones, 1992 Jennings, 1994	DWD
DV-1 (Unnamed)	NO	7	Mualchin and Jones, 1992 Jennings, 1994	DV1
EAGLE ROCK*	XX	6	Jennings, 1994	ERK
EARTHQUAKE VALLEY	ST	6 ½	Real and others, 1978 Mualchin and Jones, 1992 Jennings, 1994	EQV
EAST ANTELOPE VALLEY	NL	6 ½	Dohrenwend, 1982 Hart and others, 1984 Mualchin and Jones, 1992	EAV

			Jennings, 1994	
EL MODENO-PERALTA HILLS*	XX	6 ½	Jennings, 1994	EMP
ELYSIAN PARK SEISMIC ZONE	RE	7	Allen, 1989 Davis and others, 1989 Hauksson, 1989 Hauksson and Jones, 1989 Jones, 1989 Stein and Yeats, 1989 Yerkes, 1989 Mualchin and Jones, 1992 Jennings, 1994	EPK
EMERSON-COPPER MOUNTAIN-GALWAY LAKE	ST	7	Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	ECG
FOREST HILL-MELONES*	NL	6 ½	Jennings, 1994	FHM
FORT SAGE*	XX	6 ¼	Jennings, 1994	FTS
FRANKLIN*	XX	6 ½	Geomatrix, 1992	FRA
GARLOCK/E	ST	7 ¾	Clark, 1973 Carter, 1980 LaViolette and others, 1980 Astiz and Allen, 1983 Mualchin and Jones, 1992 Jennings, 1994	GLE
GARLOCK/W	ST	7 ¾	Clark, 1973 Carter, 1980 LaViolette and others, 1980 Astiz and Allen, 1983 Mualchin and Jones, 1992 Jennings, 1994	GLW
GARNET HILL*	XX	6 ½	Jennings, 1994	GHL
GENOA	NL	7 ¼	Dohrenwend, 1982 Bell, 1984 Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	GNA
GILLEM*	XX	6 ¾	Jennings, 1994	GLM
GILLIS MOUNTAIN*	XX	6 ½	Jennings, 1994	GMT
GOODYEARS CREEK*	NL	6 ½	Jennings, 1994	GYC
GOOSE LAKE (Alturas Sheet)	NL	6	Gay and Aune, 1958 Real and others, 1978 Nakata and others, 1982 Mualchin and Jones, 1992 Jennings, 1994	GLA
GOOSE LAKE* (Redding Sheet)	XX	6 ¼	Jennings, 1994	GLR

GORDA PLATE NE*	XX	7 ½	Jennings, 1994	GPL
GRAVEL HILLS-HARPER-HARPER LAKE	ST	7	Dibblee, 1967 Hsu and Wagner, in prep. Mualchin and Jones, 1992 Jennings, 1994	GHH
GREEN VALLEY	ST	6 ¾	Wagner and Bortugno, 1982 Hart and others, 1983 Mualchin and Jones, 1992 Jennings, 1994	GVY
GREENVILLE	ST	7 ¼	Bonilla and others, 1980 Bolt and others, 1981 Hart and others, 1981 Mualchin and Jones, 1992 Jennings, 1994	GVE
HARTLEY SPRINGS	NL	6 ½	Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	HSP
HAT CREEK	NL	6 ¾	MacDonald, 1966 Mualchin and Jones, 1992 Jennings, 1994	HCK
HAYWARD	ST	7 ½	Slemmons and Chung, 1982 Mualchin and Jones, 1992 Jennings, 1994	HWD
HELENDALE	ST	7 ¼	Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	HDE
HIDDEN SPRINGS* (San Andreas/S)	ST	6 ½	Jennings, 1994	HSS
HILTON CREEK	NL	7	Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	HLC
HOMESTEAD VALLEY	ST	6 ¾	Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	HVY
HONDA*	XX	6 ¼	Jennings, 1994	HND
HONEY LAKE	ST	7 ¼	Nakata and others, 1982 Mualchin and Jones, 1992 Jennings, 1994	HLK
HOSGRI/E	RO	7 ½	Buchanan-Banks and others, 1978 Real and others, 1978 McCulloch and others, 1980 and 1982 Clark and others, 1984 Crouch and others, 1984 GEOFON, 1985	HOE

			Greene and Kennedy, 1988a Pacific Gas and Electric, 1988 Mualchin and Jones, 1992 Jennings, 1994	
HOSGRI/W	RO	7 ½	Buchanan-Banks and others, 1978 Real and others, 1978 McCulloch and others, 1980 and 1982 Clark and others, 1984 Crouch and others, 1984 GEOFON, 1985 Greene and Kennedy, 1988a Pacific Gas and Electric, 1988 Mualchin and Jones, 1992 Jennings, 1994	HOW
HOT SPRINGS* (San Andreas/S)	XX	6 ½	Jennings, 1994	HTA
HOT SPRINGS (San Jacinto Zone)	ST	6 ½	Mualchin and Jones, 1992 Jennings, 1994	HTJ
HUNTING CREEK	ST	6 ¾	Hart and others, 1983 Mualchin and Jones, 1992 Jennings, 1994	HCR
IKES MOUNTAIN*	XX	6	Jennings, 1994	IMT
INDEPENDENCE	NL	7	Mualchin and Jones, 1992 Jennings, 1994	IND
INDIAN HILL-CUCAMONGA	RE	7	Mualchin and Jones, 1992 Jennings, 1994	IHC
INDIAN VALLEY*	XX	6 ¼	Jennings, 1994	IVY
JOHNSON VALLEY	ST	6 ¾	Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	JVY
KERN FRONT	NL	6 ¼	Bartow, 1984 Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	KFT
KERN GORGE	NL	7	Bartow, 1984 Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	KGE
KING CITY-RELIZ	ST	7	Dibblee, 1976 Buchanan-Banks and others, 1978 Mualchin and Jones, 1992 Jennings, 1994	KCR
KONOCTI BAY FAULT ZONE	NO	6 ¼	Hart and others, 1983 Mualchin and Jones, 1992	KOB

			Jennings, 1994	
KRAMER HILLS*	XX	6 ¼	Jennings, 1994	KRH
LAGUNA SALADA/E	ST	7 ¼	Fuis and others, 1982 Sharp, 1982 Kahle and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	LSE
LAGUNA SALADA/W	ST	7 ¼	Fuis and others, 1982 Sharp, 1982 Kahle and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	LSW
LAKE CITY (Likely)*	ST	6	Jennings, 1994	LCL
LAKE MOUNTAIN*	XX	6 ¼	Jennings, 1994	LMT
LAKE TAHOE (Tahoe)	NL	6 ½	Mualchin and Jones, 1992 Jennings, 1994	LTH
LANDERS E'QUAKE	ST	7 ½	Sieh and others, 199x	LEQ
LARKIN LAKE	NO	6 ½	Dohrenwend, 1982 Mualchin and Jones, 1992 Jennings, 1994	LLK
LB-1* (Unnamed)	XX	6 ¾	Jennings, 1994	LB1
LB-2/E* (Unnamed)	XX	6	Jennings, 1994	L2E
LB-2/W* (Unnamed)	XX	6	Jennings, 1994	L2W
LENWOOD-OLD WOMAN SPRINGS/E	NO	7 ¼	Dibblee, 1967 Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	LOE
LENWOOD-OLD WOMAN SPRINGS/W	NO	7 ¼	Dibblee, 1967 Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	LOW
LEUHMANN*	XX	6 ½	Jennings, 1994	LMN
LIONS HEAD	RE	6 ½	Hart and others, 1986 Mualchin and Jones, 1992 Jennings, 1994	LHD
LITTLE LAKE	ST	7	Roquemore, 1981 Mualchin and Jones, 1992 Jennings, 1994	LLK
LITTLE SALMON-YAGER	RE	7	Hart and others, 1983 Carver, 1989 Carver and others, 1989 Clarke and Carver, 1989 Mualchin and Jones, 1992 Jennings, 1994	LSY

LLANO*	XX	6	Jennings, 1994	LLO
LOCKHART	ST	7 ¼	Bortugno and Spittler, 1986 Hsu and Wagner, in prep. Mualchin and Jones, 1992 Jennings, 1994	LHT
LOCKHART/S	ST	7 ¼	Bortugno and Spittler, 1986 Hsu and Wagner, in prep. Mualchin and Jones, 1992 Jennings, 1994	LHS
LOS ALAMITOS*	XX	6	Jennings, 1994	LAO
LOS ALAMOS-BASELINE	RE	6 ¾	Ziony and others, 1974 Buchanan-Banks and others, 1978 GEOFON, 1985 Hart and others, 1986 Mualchin and Jones, 1992 Jennings, 1994	LAB
LOS OSOS	RE	6 ¾	Pacific Gas and Electric, 1988 Mualchin and Jones, 1992 Jennings, 1994	LOS
MAACAMA-BRUSH	ST	7 ¼	Toppozada and others, 1979 Pampeyan and others, 1981 Wagner and Bortugno, 1982 Hart and others, 1983 Mualchin and Jones, 1992 Jennings, 1994	MBM
MAD RIVER/C	RE	6 ¾	Real and others, 1978 Hart and others, 1983 Mualchin and Jones, 1992 Jennings, 1994	MAC
MAD RIVER/N	RE	6 ¾	Real and others, 1978 Hart and others, 1983 Mualchin and Jones, 1992 Jennings, 1994	MAN
MAD RIVER/S	RE	6 ¾	Real and others, 1978 Hart and others, 1983 Mualchin and Jones, 1992 Jennings, 1994	MAS
MAHOGANY MOUNTAIN*	XX	6 ½	Jennings, 1994	MMT
MALIBU COAST-SANTA MONICA-HOLLYWOOD-RAYMOND	RO	7 ½	Greene and Kennedy, 1986 Mualchin and Jones, 1992 Jennings, 1994	MMR
MALIBU COAST/S* (Offshore)	RO	6 ½	Jennings, 1994	MCS
MANIX	ST	6 ¾	McGill and others, 1988 Mualchin and Jones, 1992	MNX

			Jennings, 1994	
MA-1* (Unnamed)	XX	6 ¾	Jennings, 1994	MA1
MAYFIELD*	XX	6 ½	Jennings, 1994	MFD
MCARTHUR*	XX	7	Jennings, 1994	MAR
MEISS LAKE*	XX	6 ¼	Jennings, 1994	MLK
MELONES FAULT ZONE	NL	6 ½	Woodward-Clyde Cons., 1977 Toppozada and others, 1978 Real and others, 1978 Mualchin and Jones, 1992 Jennings, 1994	MLS
MENDOCINO-MATTOLE CANYON	ST	8	Real and others, 1978 Greene and Kennedy, 1988d Mualchin and Jones, 1992 Jennings, 1994	MMC
MESA-RINCON CREEK*	XX	7	Jennings, 1994	MRC
MESQUITE LAKE	ST	6 ¾	Mualchin and Jones, 1992 Jennings, 1994	MQL
MIDWAY- SAN JOAQUIN/N*	XX	6 ¾	Jennings, 1994	MSJ
MIRAGE VALLEY	ST	6 ½	Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	MVY
MOHAWK VALLEY	NL	6 ½	Woodward-Clyde Cons., 1977 Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	MOV
MONO LAKE	NL	7	Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	MOL
MONTE VISTA/E*	XX	6 ½	Jennings, 1994	MVE
MONTE VISTA/W*	XX	6 ½	Jennings, 1994	MVW
MONTEREY BAY ZONE	RO	6 ½	Greene, 1977 Buchanan-Banks and others, 1978 Greene and Kennedy, 1988a Mualchin and Jones, 1992 Jennings, 1994	MBY
MORE RANCH-MISSION RIDGE-ARROYO PARIDA-SANTA ANA	NO	7 ½	Weber and others, 1975 Buchanan-Banks and others, 1978 Greene and Kennedy, 1986 Mualchin and Jones, 1992 Jennings, 1994	MMA
MORONGO VALLEY-PINTO MOUNTAIN/N	RE	7	Proctor, 1968 Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	MPN

MORONGO VALLEY-PINTO MOUNTAIN/S	RE	7	Proctor, 1968 Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	MPS
MOUNT GENERAL*	XX	6 ½	Jennings, 1994	MGL
MOUNT HEBRON*	XX	6 ½	Jennings, 1994	MHN
MULE SPRING	RE	7	Hsu and Wagner, in prep. Mualchin and Jones, 1992 Jennings, 1994	MSP
MURIETTA HOT SPRING*	XX	6	Jennings, 1994	MHS
NELSON-CORRAL*	XX	6 ¾	Jennings, 1994	NCL
NEWPORT-INGLEWOOD-ROSE CANYON/E	ST	7	Mualchin and Jones, 1992 Jennings, 1994	NIE
NEWPORT-INGLEWOOD-ROSE CANYON/W	ST	7	Mualchin and Jones, 1992 Jennings, 1994	NIW
NORTH HOLLYWOOD*	XX	6	Jennings, 1994	NHD
NORTHERN DEATH VALLEY-FURNACE CREEK	ST	8	Mualchin and Jones, 1992 Jennings, 1994	NDF
OAKRIDGE	RO	7 ½	Weber and others, 1975 Greene and others, 1978 Greene and Kennedy, 1986 Mualchin and Jones, 1992 Jennings, 1994	OKE
OCEANIC-WEST HUASNA	RO	7 ¼	Buchanan-Banks and others, 1978 Kilbourne and Mualchin, 1980a Hall, 1982 GEOFON, 1985 Hart and others, 1986 Pacific Gas and Electric, 1988 Mualchin and Jones, 1992 Jennings, 1994	OWH
OCEANO	RE	6	Pacific Gas and Electric, 1988 Mualchin and Jones, 1992 Jennings, 1994	OCO
OIL FIELDS FAULT ZONE/N	NL	6 ¼	Bartow, 1984 Hart and others, 1984 Real and others, 1978 Mualchin and Jones, 1992 Jennings, 1994	OFN
OIL FIELDS FAULT ZONE/S	NL	6 ¼	Bartow, 1984 Hart and others, 1984 Real and others, 1978 Mualchin and Jones, 1992	OFS

			Jennings, 1994	
O'NEILL*	XX	6 ½	Jennings, 1994	ONL
ORTIGALITA/E	ST	7	Anderson and others, 1982 Hart and others, 1986 Mualchin and Jones, 1992 Jennings, 1994	ORE
ORTIGALITA/W	ST		Anderson and others, 1982 Hart and others, 1986 Mualchin and Jones, 1992 Jennings, 1994	ORW
OWENS VALLEY	ST	8	Bryant, 1984 Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	OVY
OWL LAKE*	XX	6 ½	Jennings, 1994	OLE
PACIFICO	XX	6 ½	Mualchin and Jones, 1992 Jennings, 1994	PCO
PAHRUMP- STATELINE	NL	7	Hewett, 1956 Streitz and Stinson, 1974 Ellis, 1989 Mualchin and Jones, 1992	PAS
PALOS VERDES	ST	7	Fischer and others, 1983 Greene and Kennedy, 1986 Mualchin and Jones, 1992 Jennings, 1994	PVS
PALOS VERDES HILLS- CORONADO BANK*	ST	7 ¾	Jennings, 1994	PVC
PANAMINT VALLEY/S- BROWN MOUNTAIN	NO	7	Bryant, 1989 Hsu and Wagner, in prep. Mualchin and Jones, 1992 Jennings, 1994	PSB
PINE MOUNTAIN*	XX	7	Jennings, 1994	PMN
PISGAH-BULLION	ST	7	Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	PIB
PITAS POINT- VENTURA	RO	7 ¼	Ziony and others, 1974 Weber and others, 1975 Greene and others, 1978 Greene and Kennedy, 1986 Mualchin and Jones, 1992 Jennings, 1994	PPV
PITTVILLE*	XX	6 ¾	Jennings, 1994	PVE
PLEITORE		7	Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	PLO
POINT LOMA*	XX	6 ½	Jennings, 1994	PTL

PRAIRIE CREEK-SPENCEVILLE-DENTMAN*	NL	6 ½	Jennings, 1994	PSD
QUIEN SABE*	XX	6 ¼	Jennings, 1994	QSE
RED HILL-ETIWANDA AVENUE*	XX	7	Jennings, 1994	RHE
RED MOUNTAIN	RE	7 ¼	Ziony and others, 1974 Weber and others, 1975 Mualchin and Jones, 1992 Jennings, 1994	RMN
REDONDO CANYON* (Offshore)	XX	6 ¼	Jennings, 1994	RCO
RIALTO-COLTON-CLAREMONT	XX	6 ¾	Jennings, 1994	RCC
RICH BAR*	NL	6 ½	Jennings, 1994	RIB
RINCONADA	ST	7 ½	Dibblee, 1976 Buchanan-Banks and others, 1978 Mualchin and Jones, 1992 Jennings, 1994	RCD
RODGERS CREEK-HEALDSBURG	ST	7	Hart and others, 1983 Mualchin and Jones, 1992 Jennings, 1994	RCH
ROUND VALLEY	NL	6 ¾	Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	RVM
RUSS*	XX	7 ½	Jennings, 1994	RUS
SALINE VALLEY-HUNTER MOUNTAIN-PANAMINT VALLEY/N	NO	7 ¼	Burchfield and others, 1987 Bryant, 1989 Mualchin and Jones, 1992 Jennings, 1994	SHP
SAN ANDREAS/C	ST	8	Mualchin and Jones, 1992 Jennings, 1994	SAC
SAN ANDREAS/CREEP	ST	7 ½	Mualchin and Jones, 1992 Jennings, 1994	SAR
SAN ANDREAS/N	ST	8	Green and Kennedy, 1988c Mualchin and Jones, 1992 Jennings, 1994	SAN
SAN ANDREAS/N* (Offshore)	XX	7	Jennings, 1994	SAO
SAN ANDREAS/S	ST	7 ¾	Proctor, 1968 Heath, 1980 Fuis and others, 1982 Sharp, 1982 Heath, 1986 Mualchin and Jones, 1992 Jennings, 1994	SAS
SAN ANDREAS/S/E*	ST	6	Jennings, 1994	SAE

SAN ANDREAS/S/W		7 ¾	Mualchin and Jones, 1992 Jennings, 1994	SAW
SAN ANTONIO*	XX	6	Jennings, 1994	SAT
SAN CAYETANO-HOLSER-DEL VALLE	RE	7 ½	Ziony and others, 1974 Weber and others, 1975 Mualchin and Jones, 1992 Jennings, 1994	SHD
SAN CLEMENTE	ST	7 ¼	Greene and Kennedy, 1986 Legg and others, 1989 Mualchin and Jones, 1992 Jennings, 1994	SCE
SAN DIEGO TROUGH*	XX	7 ½	Jennings, 1994	SDT
SAN FERNANDO-SIERRA MADRE-DUARTE	SSD	7 ½	Mualchin and Jones, 1992 Jennings, 1994	SSD
SAN GABRIEL	RO	7 ½	Crowell, 1975 Weber and others, 1975 Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	SGL
SAN GORGONIO MOUNTAIN	XX	6	Jennings, 1994	SGM
SAN GORGONIO PASS*	XX	6 ½	Jennings, 1994	SGP
SAN GREGORIO-PALO COLORADO	ST	7 ½	McCulloch and others, 1980 Greene and Kennedy, 1988b Mualchin and Jones, 1992 Jennings, 1994	SGC
SAN JACINTO	ST	7 ½	Fuis and others, 1982 Mualchin and Jones, 1992 Jennings, 1994	SJO
SAN JOAQUIN/S*	XX	6 ½	Jennings, 1994	SJS
SAN JOSE	RE	6 ¾	Bortugno and Spittler, 1986 Mualchin and Jones, 1992 Jennings, 1994	SJE
SANTA CRUZ ISLAND*	ST	7	Greene and Kennedy, 1986; 1988a Mualchin and Jones, 1992 Jennings, 1994	SCI
SANTA CRUZ-SANTA CATALINA RIDGE*	ST	7 ½	Jennings, 1994	SSC
SANTA MARIA RIVER-FOXEN CANYON	RE?	6 ½	Moore and Taber, 1974 Buchanan-Banks and others, 1978 GEOFON, 1985 Hart and others, 1986 Mualchin and Jones, 1992 Jennings, 1994	SMF

SANTA ROSA ISLAND ISLAND	ST	7	Greene and Kennedy, 1988a Mualchin and Jones, 1992 Jennings, 1994	SRI
SANTA SUSANA	RE	7	Weber and others, 1975 Mualchin and Jones, 1992 Jennings, 1994	SSA
SANTA YNEZ	RO	7 ½	Rice and others, 1981 Mualchin and Jones, 1992 Jennings, 1994	SYZ
SANTA YNEZ (SOUTH BRANCH)	NO	7 ½	Rice and others, 1981 Mualchin and Jones, 1992 Jennings, 1994	SYS
SANTA YNEZ RIVER*	XX	7 ½	Jennings, 1994	SYR
SA-1* (Unnamed)	XX	6 ½	Jennings, 1994	SA1
SARGENT	ST	6 ¾	Prescott and Burford, 1976 Hart and others, 1981 Mualchin and Jones, 1992 Jennings, 1994	SRT
SIERRA NEVADA	NL	7 ¾	Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	SNA
SILVER LAKE	NL	6 ½	Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	SLE
SIMI-SANTA ROSA- NORTHRIDGE HILLS	RO	7 ½	Ziony and others, 1974 Weber and others, 1975 Mualchin and Jones, 1992 Jennings, 1994	SSN
SLINKARD VALLEY	NL	6 ¼	Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	SVY
SLO-1* (Unnamed)	XX	6 ¼	Jennings, 1994	SLO
SODA CREEK	ST	6 ¼	Wagner and Bortugno, 1982 Hart and others, 1983 Mualchin and Jones, 1992 Jennings, 1994	SCK
SOUTHAMPTON*	XX	6 ¼	Geomatrix, 1992	SHP
SR-1/E* (Unnamed)	XX	6	Jennings, 1994	SRE
SR-1/W* (Unnamed)	XX	6	Jennings, 1994	SRW
SS-1* (Unnamed)	XX	6 ½	Jennings, 1994	SS1
STAMPEDE VALLEY	ST	6 ½	Real and others, 1978 VanWormer and others, 1979	STV

			Gasch and Associates, 1984 Mualchin and Jones, 1992 Jennings, 1994	
SU-4 (Unnamed, Nevada)	NL	6 ½	Nakata and others, 1982 Stewart and Carlson, 1978 Mualchn and Jones, 1992	SU4
SUPERSTITION HILLS	RO	7	Fuis and others, 1982 Mualchin and Jones, 1992 Jennings, 1994	SUH
SUR-ARROYO LAGUNA-SAN SIMEON	ST	7 ½	Mualchin and Jones, 1992 Jennings, 1994	SLS
SURPRISE VALLEY	NL	7	Hedel, 1984 Mualchin and Jones, 1992 Jennings, 1994	SUV
SU-6* (Unnamed)	XX	6 ¼	Jennings, 1994	SU6
SU-3 (Unnamed, Nevada)	NL	6 ½	Mualchin and Jones, 1992	SU3
SWEETWATER	NO	6 ½	Dohrenwend, 1982 Mualchin and Jones, 1992 Jennings, 1994	SWR
TANK CANYON*	XX	6	Jennings, 1994	TCN
TOWNE PASS*	XX	6 ¾	Jennings, 1994	TPS
TRINIDAD*	XX	7 ½	Jennings, 1994	TRD
TR-1 ST (Unnamed)		6 ½	Hsu and Wagner, in prep. Mualchin and Jones, 1992 Jennings, 1994	TR1
TR-2* (Unnamed)	XX	6 ½	Jennings, 1994	TR2
TULARCITOS-NAVY	ST	7	Mualchin and Jones, 1992 Jennings, 1994	TNY
VACA-KIRBY HILL-MONTEZUMA HILLS/E*	XX	6 ¾	Jennings, 1994	VME
VACA-KIRBY HILL-MONTEZUMA HILLS/W*	XX	6 ¾	Jennings, 1994	VMW
VERDUGO	RO	6 ¾	Ziony and others, 1974 Mualchin and Jones, 1992 Jennings, 1994	VDO
VERONA-WILLIAMS*	XX	6	Jennings, 1994	VWS
WARM SPRINGS VALLEY*	XX	6 ¼	Jennings, 1994	WSV
WATERMAN CANYON*	XX	6 ¾	Jennings, 1994	WCN
WEST NAPA	NO	6 1/2	Wagner and Bortugno, 1982 Hart and others, 1983 Mualchin and Jones, 1992 Jennings, 1994	WNP

WEST WALKER RIVER	NL	6	Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	WWR
WHALE GULCH- BEAR HARBOR*	XX	7 ½	Jennings, 1994	WBH
WHEELER RIDGE	RE	7	Hart and others, 1984 Real and others, 1978 Mualchin and Jones, 1992 Jennings, 1994	WRE
WHITE CANYON- RED HILLS-GILLIS CANYON-SAN JUAN*	XX	7	Jennings, 1994	WRS
WHITE MOUNTAINS/N	NL	7 ½	Stewart and Carlson, 1978 Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	WMN
WHITE MOUNTAINS/S	NL	7 ½	Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	WMS
WHITE WOLF	RO	7 ¾	Bartow, 1984 Hart and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	WWF
WHITTIER-ELSINORE	ST	7 ½	Kahle and others, 1984 Mualchin and Jones, 1992 Jennings, 1994	WEE
WL-1 (Unnamed)	NO	6 ½	Dohrenwend, 1982 Mualchin and Jones, 1992 Jennings, 1994	WL1
WL-2 (Unnamed)	NO	7 ¼	Dohrenwend, 1982 Mualchin and Jones, 1992 Jennings, 1994	WL2
YUHA WELLS*	XX	6	Jennings, 1994	YWS
ZAYANTE- VERGALES	ST	7 1/4	Buchanan-Banks and others, 1978 Jennings, 1975	ZVS

(for footnotes see next page)

1) Unnamed faults indicated by abbreviated Geologic Atlas Sheet name. If fault lies in Nevada, the name is followed by NV.

<u>Atlas Sheet Abbreviations</u>

AL = Alturas
DV = Death Valley
LB = Long Beach
MA = Mariposa
SA = Santa Ana
SLO = San Luis Obispo
SR = Santa Rosa
SS = Salton Sea
SU = Susanville
TR = Trona
WL = Walker Lake

2) Style of faulting:

NL = normal
NO = normal-oblique
RE = reverse, including thrust
RO = reverse-oblique
ST = strike-slip
XX = not known/published

3) Magnitude in Moment Magnitude (Mw) scale to the nearest quarter unit.

* New earthquake sources.

14. FIGURE 1

Attenuation curves: Mualchin and Jones (1992).